CHAPTER 1 INTRODUCTION

1.1 PROJECT DESCRIPTION

This project, the 2006 Update to the Montana Aviation System Plan, continues development of a Pavement Management System for Montana's general aviation airports. This is an ongoing process begun in 1988 and updated on a three-year cycle since then. The Aeronautics Division of the Montana Department of Transportation, in coordination with the Federal Aviation Administration, Helena Airports District Office, contracted with Robert Peccia and Associates to provide the surveys and analysis required for this phase of the pavement management system development.

The pavement management system is designed to be a systematic, and objective tool for determining maintenance and rehabilitation needs and priorities for paved surfaces on Montana's general aviation airports. As such, it is intended to provide better information to airport and aviation officials, so that Federal, State, and local resources can be more efficiently allocated toward maintaining and improving airport pavements. The Pavement Condition Index (PCI) provides a dependable scale for comparing the existing operational condition and structural integrity of airport pavements. The pavement management system's PCI provides a rational basis for justifying pavement replacement or rehabilitation projects. It can also provide feedback on pavement performance to validate or revise pavement design, construction, and maintenance procedures.

The project consists of airport pavement records updates, map updates (FAA Form 5320-1), pavement condition surveys, PCI calculations, PCI analyses, PCI predictions, maintenance suggestions, and maintenance budget projections. This final report documents work completed, assesses system-wide conditions and potential, and recommends work for future updates to the pavement management system. Inspection results, PCI values, predictions, maintenance suggestions, and brief interpretation of the results are provided directly to the sponsor for each airport. Results will be provided in electronic format to Montana Aeronautics Division for inclusion in their web site.

Airport maps and pavement records (FAA Form 5320-1) were updated in digital format for fifty (50) airports. These airports also had intensive field inspections of pavement samples, collecting data to estimate current and future airport conditions. Pavement deterioration at all fifty-nine (59) general aviation airports in Montana's database were forecast at 1-, 5-, and 10-years using the Pavement Condition Index.

Field surveys were performed in accordance with the criteria specified in Federal Aviation Administration (FAA) Advisory Circular AC 150/5380-6 "Guidelines and Procedures for Maintenance of Airport Pavements". Calculations, analysis, and predictions were accomplished using the U.S. Army Corps of Engineers Construction Engineering Research Laboratory's (USACERL) "MicroPAVER" software system (versions 5.3.2 through 5.3.4).

Table 1.1 and Figure 1.1 show the airports surveyed and analyzed in this project.

1.2 THE PAVEMENT MANAGEMENT SYSTEM

A pavement management system begins with an objective, repeatable method for determining present pavement condition. This project uses the Pavement Condition Index (PCI) developed at the US Army Corps of Engineers Research Lab (USACERL). The PCI is a numerical index from 0 to 100 that describes the pavement's overall structural integrity and operational condition, with 100 assigned to a new pavement with no flaws and zero to a highly degraded pavement. The PCI is based on the types, severities, and quantities of pavement distresses identified during on-site visual inspections.

A computerized database called MicroPAVER is used to store, manipulate, and present data that generates PCI values. This program was developed at US Army's Construction Engineering Research Laboratory specifically for use with the PCI. The MicroPAVER system is continually being improved and upgraded by Engineered Management Systems Software and is periodically reissued in a new version. Montana's pavement management system typically uses the most recent release of the software. The newer software has strived to enhance analysis and reporting tools, refine analysis routines, and improve the operator-computer interface. The current upgrade is a Windows-based program with reasonably easy data transfer and query routines. For this report MicroPAVER output was refined and supplemented using WordPerfect, Microsoft Excel, and Microsoft Access to improve readability and condense the formatting.

As with any pavement management system, the following tasks are required to adequately document the process, obtain the required field data, and generate meaningful results.

- Assemble background data about the pavements to be studied.
- Prepare and update base maps, define the study areas.
- Conduct field inspections.
- Process the field inspection and background data.
- Analyze the data and generate appropriate reports.

The process begins with reviewing airport records to locate the pavements to be studied. Background information such as materials, thicknesses, construction dates, primary use (runway/taxiway/apron), surface area, and related data is assembled. This data is then used to divide pavements into a successively refined network by geographic location, functional use, consistency of characteristics, and manageable inspection size.

Each airport is considered a separate "zone" in Montana's airport database. Each zone (airport) is then divided by function or primary use into "branches." All aprons are grouped into a single branch, all taxiways into another branch, and each runway is placed in a separate branch. Branches are further divided into "sections" with similar characteristics. Each section is defined as a pavement of consistent age, construction materials, and maintenance history. Finally, since sections are generally still large pavement areas, each is divided as evenly as possible into "sample units." This last division of asphalt-surfaced areas into near 5000 square foot samples, and concrete-surfaced areas into near 20 slab samples is designated for convenient, manageable, and statistically valid pavement inspection.

After obtaining background information and dividing the pavements into zones, branches, sections, and sample units, the database network is created and base maps are drawn to document this network structure.

FAA Forms 5320-1, "Pavement Strength Survey" are revised and used as guides during field surveys. Base map layout is confirmed (or adjusted) on-site during visual pavement inspection.

As field inspections are completed, distress data is loaded into the MicroPAVER program. Pavement Condition Indexes are calculated providing a numerical rating of present condition by section. Sections are grouped by similar construction, strength, and primary use into "families" of pavements which should experience similar wear, deterioration, and useful lives. The PCI history of all pavements in a family are used to generate a pavement life cycle curve which can then be used to forecast PCI's for all member pavements in the family.

Finally, when the desired analyses have been completed, numerous reports can be generated to describe the pavement systems, their existing conditions, their approximate future conditions, and potential costs to improve performance and extend pavement life.

1.3 SCOPE OF SERVICES

The scope of services required for this phase of the pavement management system development consist of the following:

- Collecting and updating airport geometric and pavement condition information for fifty (50) airports;
- Updating base maps (FAA Form 5320-1) for the 50 airports whose pavement information has been reviewed. These maps are produced in AutoCAD and transferred to the more readily accessible Adobe PDF format. These maps are provided in hard copy and digital formats, for continued use in pavement management system updates;
- Define pavement zones, branches, sections, and sample units for any reconstruction, or new construction of airside pavements.
- Conduct visual condition surveys at 50 general aviation airports located throughout the State of Montana, load the survey data into MicroPAVER, and obtain current PCI values for each section;
- Develop "Family Analysis Curves" to model pavement performance by comparing similar pavements to one another. Predict future pavement conditions by using the Family Analysis Curves.
- Updating the State's MicroPAVER database, analyzing pavements, and producing summary reports for each airport studied;
- Providing the Owner and airport sponsors with pavement analysis results and recommendations based on the study.

maintenance spikes. A combination of factors may conspire to rapidly degrade a specific pavement -- excess moisture destabilizing the subgrade, poor construction practices, abuse, or overloading, Another branch could have all the luck (and care) - solid subgrade, conscientious construction, light usage, wintering the freeze-thaw cycles under an insulating blanket of snow. Uncommon PCI's are filtered out with best- and worst-case scenario boundaries. Occassionally, a section or two may be removed from the family construction due to the engineer's determination of irregular circumstances.

FAMILY NAMES:

ACPL, ACAM, ACRML, ACRMU, ACAH, ACRH, STPA, PCAA

FAMILY NAME CODING:

1st two letters = surface type
- AC = all asphalt cement pavements
- PC = all Portland cement pavements
- ST = surface treatment

3rd letter = primary use
- A = aprons
- R = runways and taxiways
- P = all primary uses (aprons, runways, and taxiways)

4th letter = design strength
- A = all strengths
- L = low strength (< 12.5K, single wheel)
- M = medium strength (12.5K - 30K, single wheel)
- H = high strength (> 30K, single wheel)

5th letter = operations count (where applicable)
- L = light use (≤ 5000 annual estimated operations)
- U = busy (over 5000 annual estimated operations, or more than 1 op./daylight hour)

Table 2.4 on the following pages summarizes pavement section data from FAA 5320-1 forms, uses it to assign section categories and surface types, and then determines the family assignment for each section in the Montana airports database. This table has been updated to include approximate annual operations counts and documents the use of geotextiles in the pavement section. Table 2.4 includes all the information used to construct family groups, and additional data that was considered for new groupings.

MicroPAVER gives the user great flexibility in defining families. The user is also free to redefine families at any time, since family definition plays a very important part in PCI predictions. As the pavement management system continues to develop, better family definitions may become apparent, and they should be revised accordingly.

After families have been defined and each pavement section is assigned to the appropriate family, MicroPAVER generates "Family Analysis Curves." These are PCI verses Age curves derived from a least-squares adjustment of all known observations within the family. Graphically speaking, each time a PCI evaluation of a section is completed, that section's PCI is plotted against its Age, forming a single data point (or observation) on that section's family analysis curve. The model is further constrained by insisting that a pavement cannot improve its condition over time (without outside intervention), so a family curve can never rise in PCI with age. The least squares adjustment then yields a single curve that is most representative of the data. In lieu of better information, the life cycle curve for pavement ages greater than any sampled in the family group is assumed to continue at the same rate of decay as at the last data point. In other words, the PCI predictions follow the straight-line tangent to the curve at the oldest pavement life.

Figures 2.3 through 2.10 illustrate the family analysis curves for the eight families defined in this project. These curves are based on actual data from pavement condition surveys spanning 1988-2006. In some cases, pavements were filtered out of the curve analyses when they fit poorly with the other data within the family, when there was a known atypical repair to specific pavements, or simply using good engineering judgement about the possible quality versus pavement age. Table 2.5 shows the assumed acceptable extreme PCI's used as boundary filters for the data.

TABLE 2.5
PCI vs. AGE - ALLOWABLE EXTREMES/BOUNDARIES

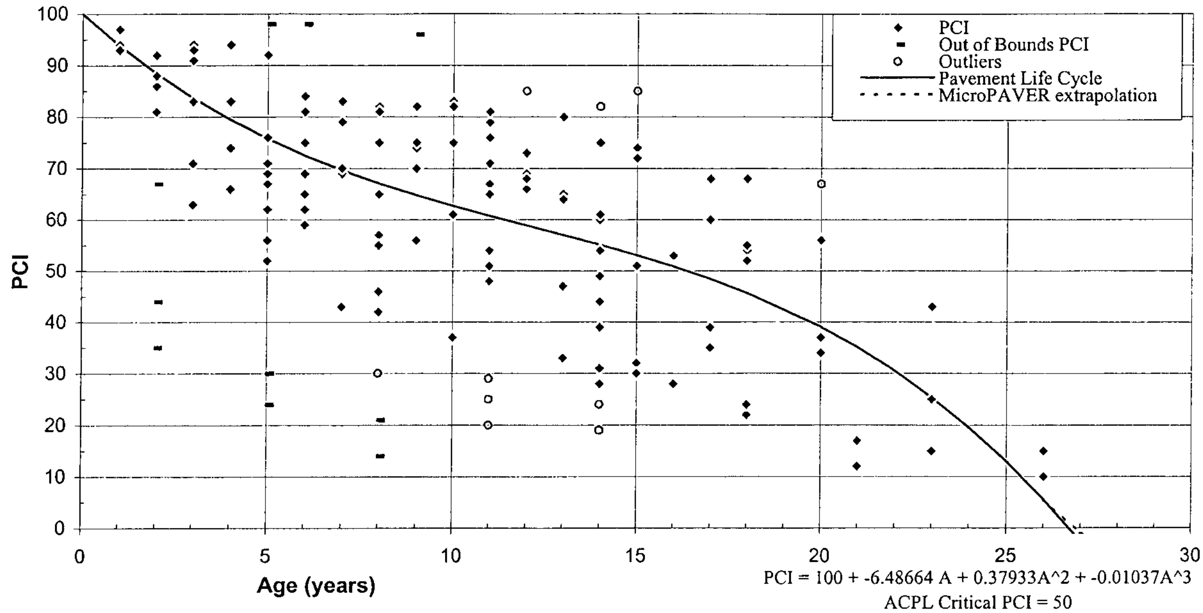
Age	Minimum PCI	Maximum PCI
0	90	100
3	58	100
5	36	95
15	0	90
20	0	86
25	0	75
30	0	64
40	0	20

Figures 2.3 through 2.10 show life cycle curves for each family as well as "valid" data points used to construct the curve, "out of bounds" data points, and "outliers" not used in the curve fit. Note that MicroPAVER uses the dashed linear projection rather than the curve for ages greater than sampled ages in the family. The family curve equation is in the lower right corner of each graph, as well as the "critical PCI" where the rate of deterioration increases markedly.

FAMILY LIFE CYCLE CURVES

FIGURE 2.3

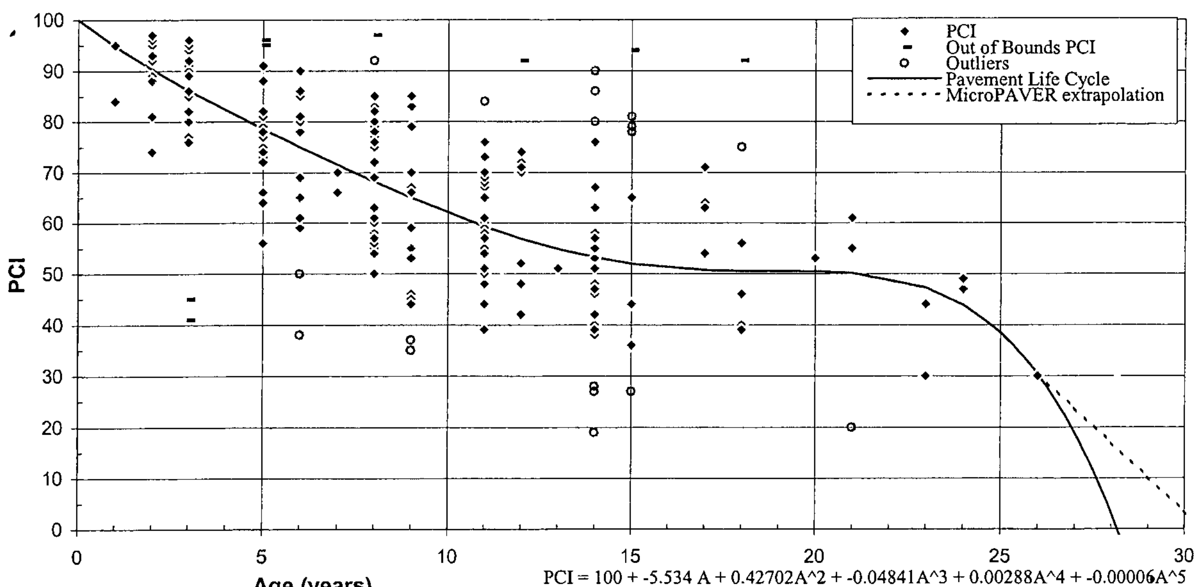
ACPL - Asphalt Pavements with less than 12,500 lb. Load Rating



PCI = 100 + -6.48664 A + 0.37933A^2 + -0.01037A^3
ACPL Critical PCI = 50

FIGURE 2.4

STPA - Bituminous Surface Treated Pavements of All Load Ratings



PCI = 100 + -5.534 A + 0.42702A^2 + -0.04841A^3 + 0.00288A^4 + -0.00006A^5
STPA Critical PCI = 50

FIGURE 2.5
ACAH - Asphalt Aprons With Higher Than 30,000 lb. Load Rating

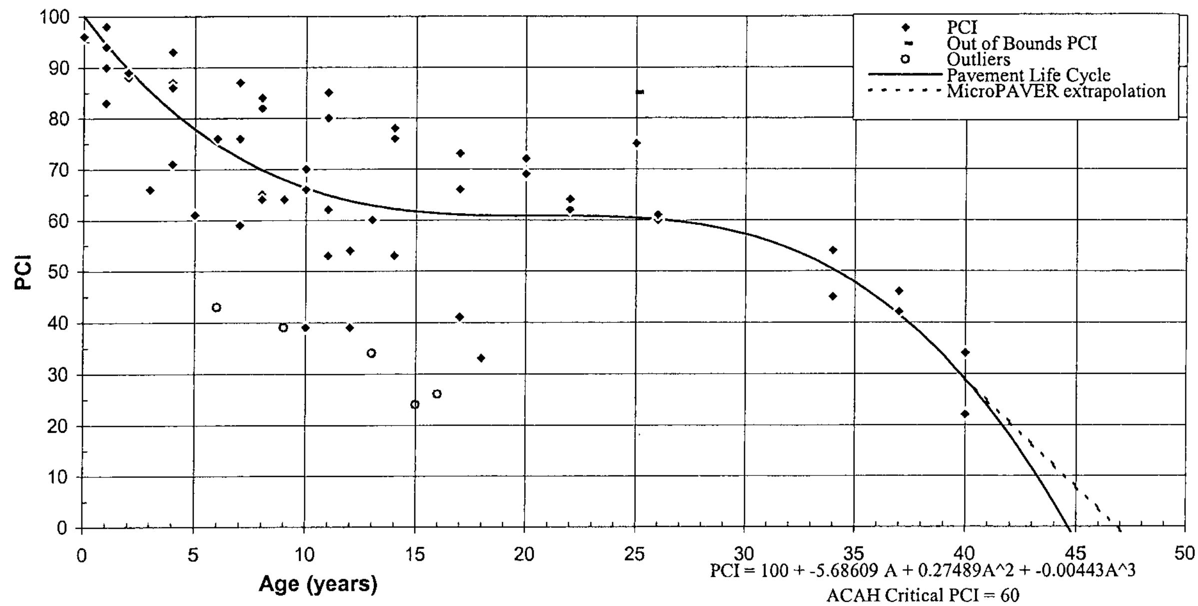


FIGURE 2.6
ACRH - Asphalt Runways And Taxiways With Higher Than 30,000 lb. Load Rating

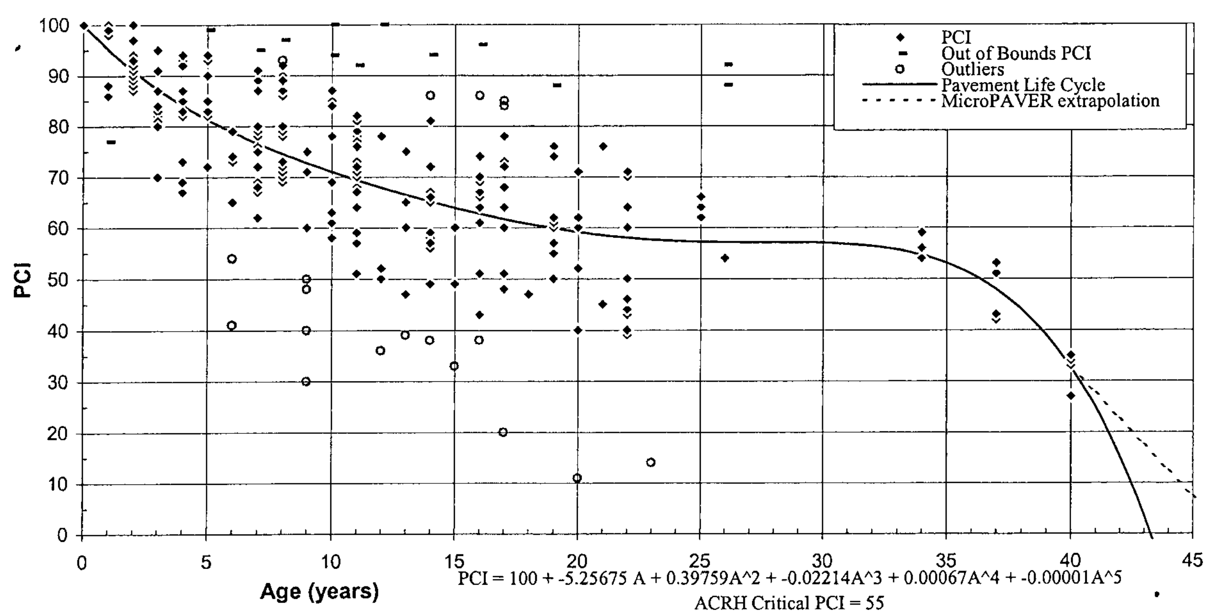
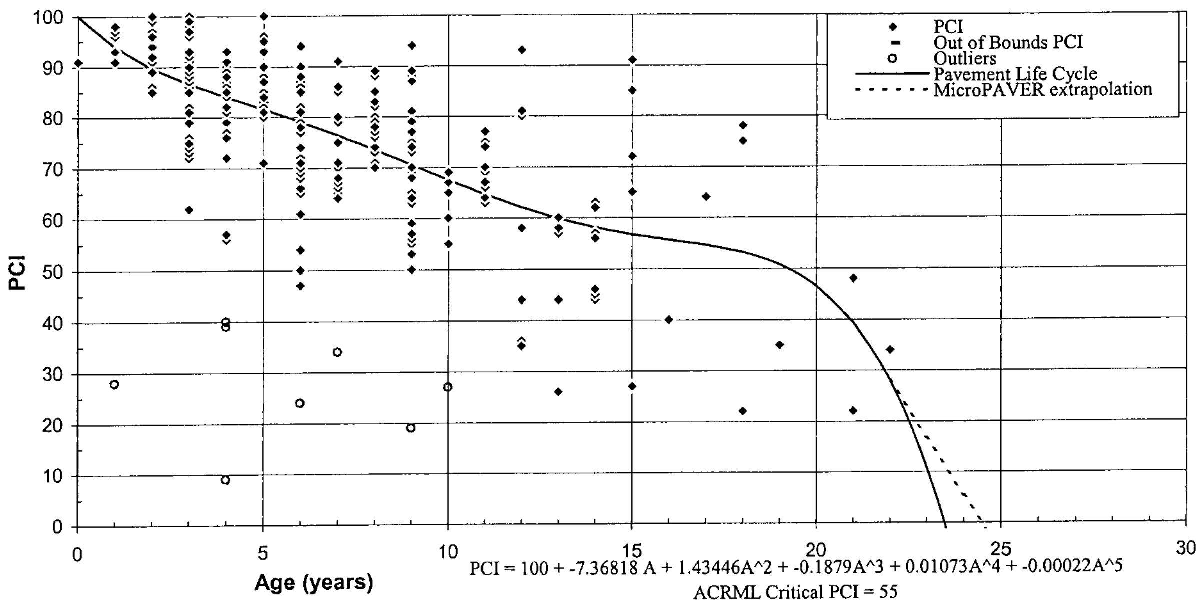


FIGURE 2.7

ACRML - Asphalt RWs And TWs, Load Rating 12,500 To 30,000 lb, 5000 or Fewer Ops.

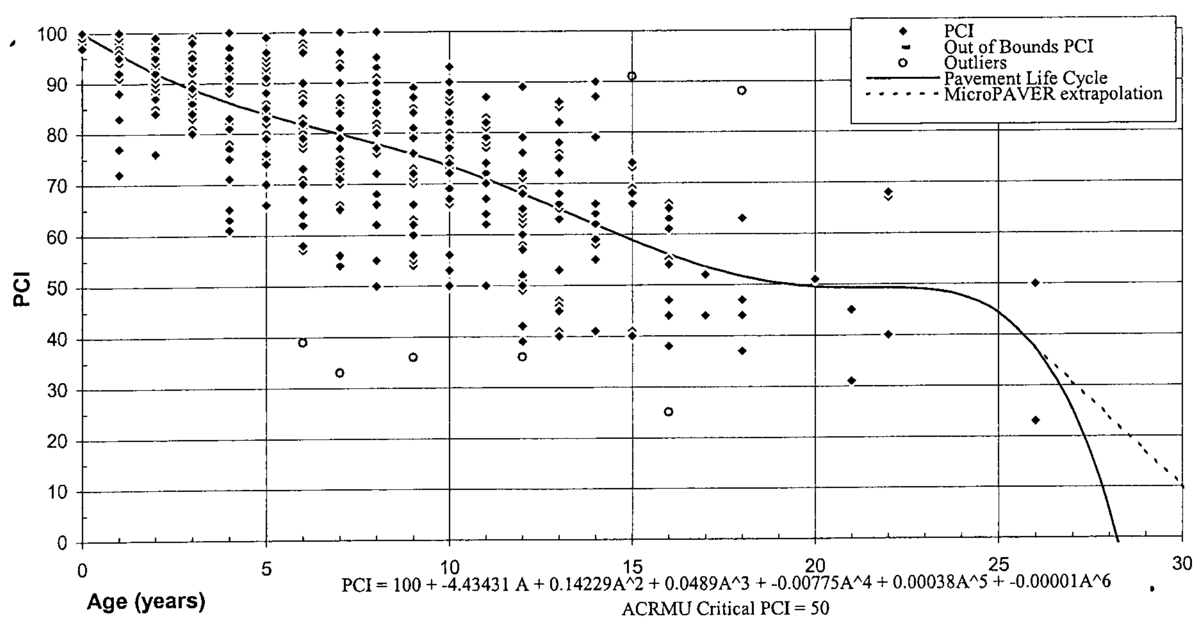


PCI = 100 + -7.36818 A + 1.43446A^2 + -0.1879A^3 + 0.01073A^4 + -0.00022A^5

ACRML Critical PCI = 55

FIGURE 2.8

ACRMU -Asphalt RWs And TWs, Load Rating 12,500 To 30,000 lb, Over 5000 Ops.



PCI = 100 + -4.43431 A + 0.14229A^2 + 0.0489A^3 + -0.00775A^4 + 0.00038A^5 + -0.00001A^6

ACRMU Critical PCI = 50

FIGURE 2.9
ACAM - Asphalt Aprons With Load Rating From 12,500 To 30,000 lb.

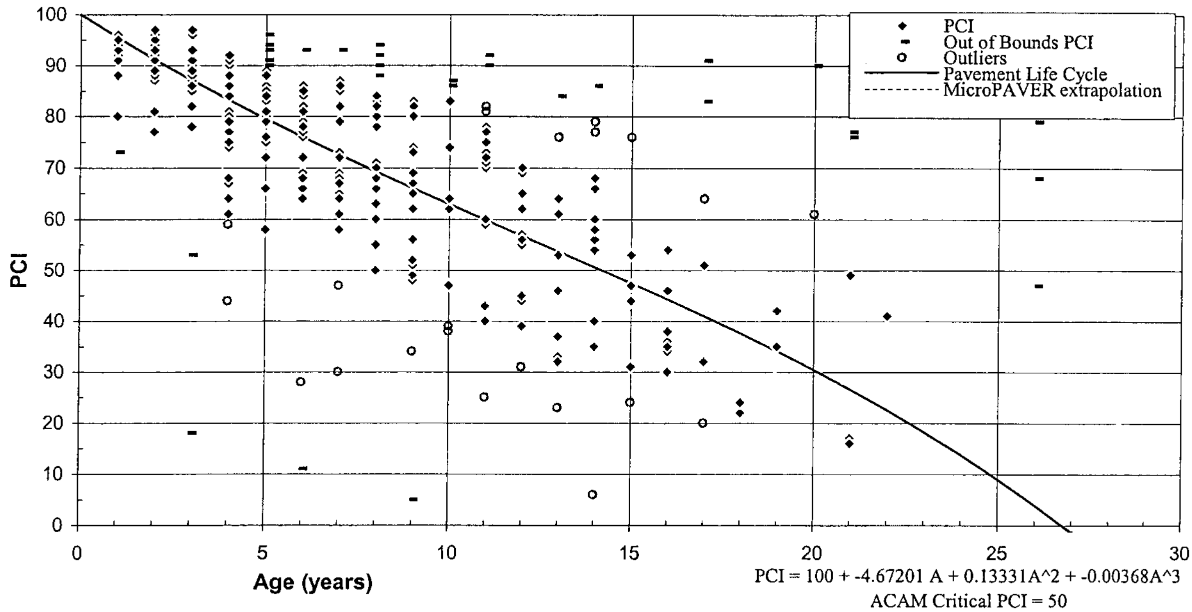
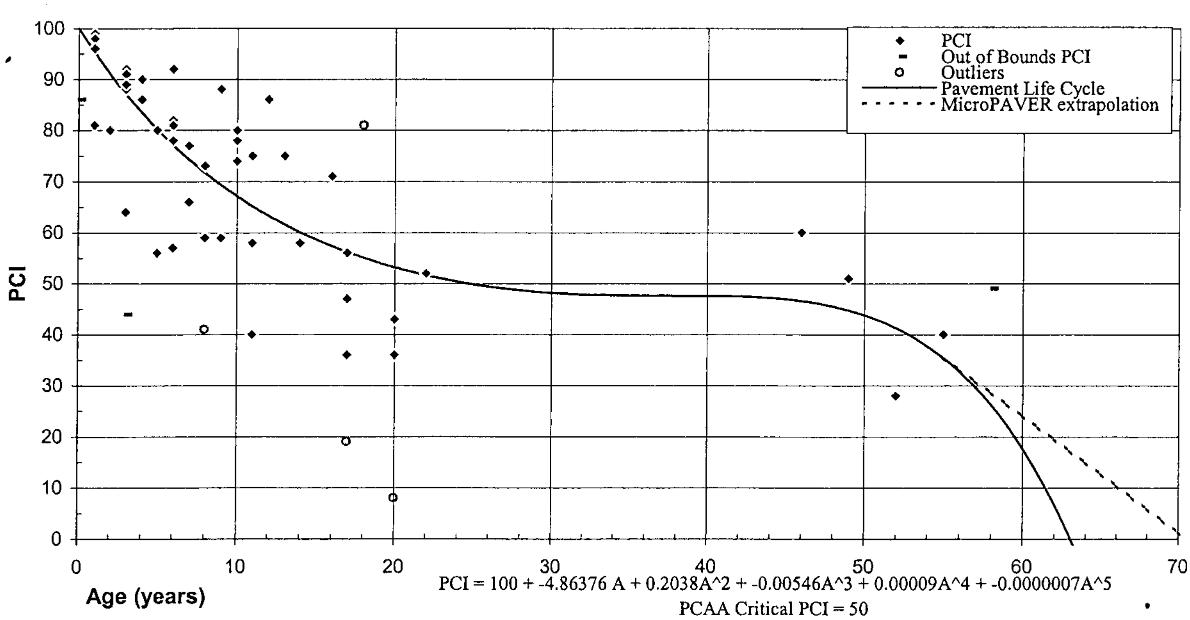


FIGURE 2.10
PCAA - Portland Concrete Cement - All Sections



Sample units were selected before arriving at the site and inspections were conducted on the preselected sample units to avoid biasing the sample. In some cases systematic random sampling was not used either due to a decidedly "non-random" interaction of sample numbers and systematic survey points that concentrated sampling in a small area, or due to an effort to sample previously unsampled areas. The Anaconda example below illustrates the most common sample selection variations. Runway 16-34, designated "R-1", has few previously sampled areas , so the recommended systematic random sampling is used. A variant of systematic random sampling using paired sample units, was used on the taxiway, T-1, to pick-up several samples with no historical inspection. Section A-1 had samples selected entirely at random since all samples had been inspected at least once during previous inspections. Finally, a minor variant of systematic sampling of apron area A-2 collects information on several previously uninspected samples disbursed across the apron, rather than using samples concentrated along one edge that would be generated from a true systematic random sampling process. Aprons especially, can require a more arbitrary selection of samples to get a good geometric distribution of samples necessary to a representative sampling.

TABLE 2.2
EXAMPLE SAMPLE UNIT SELECTION

ANACONDA AIRPORT

Section Number	Total # of Sample Units (N)	Minimum # of Units to Inspect * (n)	Sample Spacing ** (I=N/n)	Random Start # (s)	Sample Units to Survey (s,s+i,s+2i,etc)	Actual Sample Units Surveyed
R-1	99	6 + 1 = 7†	14	3	3,7,31,45,59,73,87	
			or		or	
			15		3,18,33,48,63,78,93	3,18,33,48,63,78,93
T-1	20	5	4	4	4,8,12,16,20	4,5,9,10,16,17
A-1	9	4	2	1	1,3,5,7 (used in '97)	3,4,5,6
				1	1,5,7,9 (variant used in '03)	
				2	2,4,6,8 (used in '94)	
			or			
			3	1	1,4,7,~~10~~ (along one edge)	
A-2	17	5	3	3	3,6,9,12, 15 (along one edge)	5,7,9,11,13
			or			
			4	2	2,6,10,14,~~18~~ (variant used in '03)	

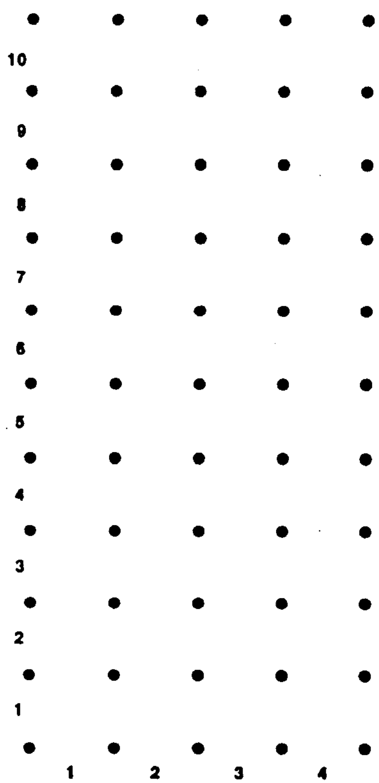
* Table 2.1, or engineer's judgement
** Rounded up or down to a whole number
†Robert Peccia & Associates' engineers chose to increase sampling frequency by 1 on all runways, to provide a higher probability of an accurate PCI assessment on this most critical airport pavement.

The airport base maps (FAA Form 5320-1) show the sections and sample units defined for each airport. Sample units selected for evaluation in the various project years are marked with different hatch patterns as shown in the map legend. Sample units selected for evaluation in the 2006 Update are gray shaded ( ).

FIGURE 2.1

CONCRETE PAVEMENT INSPECTION SHEET

Branch ____________ Section ____________
Date ____________ Sample Unit ____________
Surveyed by ____________ Slab Size ____________



Distress Types

61. BLOW-UP
62. CORNER BREAK
63. LONG / TRANS / DIAGONAL CRACK
64. DURABILITY CRACK
65. JOINT SEAL DAMAGE
66. PATCHING, < 5 SF
67. PATCHING / UTILITY CUT
68. POPOUTS
69. PUMPING
70. SCALING / MAP CRACK / CRAZING
71. SETTLEMENT/FAULT
72. SHATTERED SLAB
73. SHRINKAGE CRACK
74. SPALLING - JOINTS
75. SPALLING - CORNER

Dist. Type	Sev.	No Slabs	% Slabs	Deduct Value
26#				
Deduct Total				
Corrected Deduct Value (CDV)				

PCI = 100 - CDV = ____________

Rating = ____________

ASPHALT PAVEMENT INSPECTION SHEET

Branch ____________ Section ____________
Date ____________ Sample Unit ____________
Surveyed by ____________ Area of Sample ____________

Distress Types

41. ALLIGATOR CRACKING
42. BLEEDING
43. BLOCK CRACKING
44. CORRUGATION
45. DEPRESSION
46. JET BLAST
47. JT. REFLECTION (PCC)
48. LONG. &TRANS. CRACKING
49. OIL SPILLAGE
50. PATCHING
51. POLISHED AGGREGATE
52. RAVELING / WEATHERING
53. RUTTING
54. SHOVING FROM PCC
55. SLIPPAGE CRACKING
56. SWELL

Sketch:

Existing Distress Types

Total Severity L						
M						
H						

PCI Calculation

Distress Type	Density	Severity	Deduct Value
Deduct Total			
Corrected Deduct Value (CDV)			

PCI = 100 - CDV = ____________

Rating = ____________

2.3 PAVEMENT CONDITION SURVEYS

Visual condition inspections were conducted in general accordance with the procedure outlined in Appendix A of the FAA Advisory Circular 150/5380-6, "Guidelines and Procedures for Maintenance of Airport Pavements". Modifications were made in accordance with the Northwest Mountain Region handout, "Pavement Condition Survey Program", (6/11/88 HLN/ADO). This handout proposes the following major changes to the procedure outlined in AC 150/5380-6.

1. The number of pavements to be surveyed was reduced by eliminating T-hangar taxiways and pavement sections smaller than 10,000 square feet.
2. The survey confidence level was reduced from 95% to 92%.

Detailed visual inspections were conducted on paved surfaces at each of the airports selected for this project during the period July 2006 through October 2006. The sections defined on base maps were verified, or revised if necessary. Sample units to be surveyed were temporarily marked on the pavement. Visual inspections were conducted measuring types, severities, and quantities of pavement distresses while walking over each selected sample unit. Distresses were recorded on inspection sheets like those shown in Figure 2.1. Individual pavement distress types and severities were identified using Appendix B of the FAA Advisory Circular 150/5380-6 and USACERL generated PCI Field Manuals for asphalt surfaced airfields and jointed concrete airfields. Photographs documenting overall condition and/or specific distresses were taken during the field surveys and are included in Chapter 4. Sample selection strives to select "representative" areas, but photos were often selected to show extreme (and possibly atypical) distresses.

After consulting with M. Y. Shahin, MicroPaver's lead development engineer, two adjustments to previous field inspections were initiated beginning in 2000. Alligator cracking within one foot of the pavement edge was recorded as longitudinal cracks, and distresses recorded as "block cracking" in 1997 were reduced to longitudinal /transverse. On larger airports, sections can be chosen to separate runway edge conditions from the commonly used center with separate PCI's produced for heavily used center and seldom used edges. With smaller GA airports, it's impractical to subdivide runway width, so edge failure can drive the PCI of a runway significantly below what its center section would warrant. Down-grading the type of distress recorded for edge failure better represents the quality of the commonly used portion of the pavement. Large, rectangular blocks seen on a few of Montana's airports were judged to be just off the block cracking continuum, and recording them as such was excessively harsh on the section PCI. These two changes brought Montana's pavement management system more in line with MicroPaver's empirical research.

2.4 PAVEMENT CONDITION INDEX (PCI)

The pavement condition index (PCI) is an objective, repeatable numerical rating or "grade" that describes the overall condition of a pavement section on a scale of 0 (failed pavement) to 100 (perfect pavement). It is based on visual inspections of manageable sample pavement areas for types, severities, and quantities of a number of specific distresses. "Field verification of the PCI inspection method has shown that the index gives a good indication of a pavement's structural integrity and operational condition. It has also been shown that, at the network level, the observation of existing distress in the pavement provides a useful index of both the current condition and an indication of future performance under existing traffic conditions."[1]

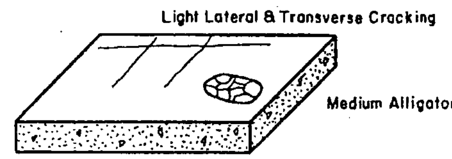
[1] USACERL Technical Report M-90/05, July 1990, Paver Update, "Pavement Maintenance Management for Roads and Streets Using the PAVER System," by M. Y. Shahin & J. A. Walther, p40.

FIGURE 2.2

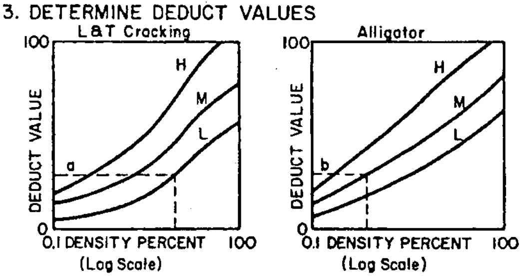
PCI CALCULATION STEPS

STEP I. DIVIDE PAVEMENT SECTION INTO SAMPLE UNITS.

STEP 2. INSPECT SAMPLE UNITS. DETERMINE DISTRESS TYPES AND SEVERITY LEVELS AND MEASURE DENSITY.

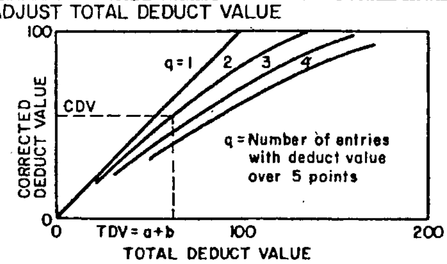


STEP 3. DETERMINE DEDUCT VALUES



STEP 4. COMPUTE TOTAL DEDUCT VALUE (TDV) a+b

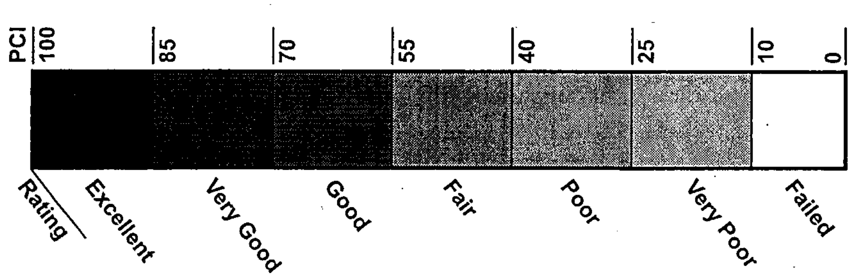
STEP 5. ADJUST TOTAL DEDUCT VALUE



STEP 6. COMPUTE PAVEMENT CONDITION INDEX (PCI) 100-CDV FOR EACH SAMPLE UNIT INSPECTED

STEP 7. COMPUTE PCI OF ENTIRE SECTION (AVERAGE PCI'S OF SAMPLE UNITS).

STEP 8. DETERMINE PAVEMENT CONDITION RATING OF SECTION



Source: USACERL Technical report M-90/05, July 1990, Paver Update, "Pavement Maintenance Management for Road & Streets Using the Paver System," by M.Y. Shahin & J.A. Walther, P41.

2.5 PCI CALCULATIONS

The PCI is produced for each surveyed sample unit with a series of calculations using the area of the sample and quantities of standard distress types as summarized in Figure 2.2. Pavements are divided into manageable sample areas and a random selection of these are intensively inspected (Figure 2.2, Step 1). Quantities of standardized distress types (descriptions and example photos in Appendix B) and severities are recorded during visual inspections by trained inspectors (Figure 2.2, Step 2). Quantities divided by the sample area give distress density for each type and severity of distress present. Distress densities are transferred to deduct values using composite curves generated from US Army Corps of Engineers pavement research (Figure 2.2, Step 3). The total deduct value is the sum of deducts due to individual distress types and severities (Figure 2.2, Step 4). To reflect the empirical fact that numerous minor defects are not as detrimental to a pavement's condition as a few major defects, this total deduct is scaled back when there are a large number of deducts recorded (Figure 2.2, Step 5). The Pavement Condition Index (PCI) is simply a perfect 100 pavement less the adjusted total deduct value (Figure 2.2, Step 6). The area-weighted average of the sample PCI's is taken as the section PCI (Figure 2.2, Step 7). There are seven discrete groupings of PCI values that describe the overall pavement quality with Pavement Condition Ratings (Figure 2.2, Step 8). The new version of MicroPAVER allows user-defined rating titles & ranges, and suggests that only PCI's above 55 are acceptable, with sub-55 PCI's rated as "poor" to "failed."

In addition to extrapolating PCI's from selected sample areas to larger sections of pavement, distress densities, distress quantities, and deducts are extrapolated for each section and included in the Inspection Report Summary. Extrapolated distress densities are the sum of distress quantities divided by the sum of the sampled areas. Distress densities are both scaled up by the section area to get extrapolated distress quantities, and also fed into the deduct curves to get extrapolated deducts for the section.

While these calculations can be completed by hand, the vast quantity of data collected for Montana's general aviation airports makes it much more feasible to use the MicroPAVER software package developed by USACERL expressly for PCI calculations. PCI's in this report were produced with MicroPAVER 5.3.2 - 5.3.4 for Windows.

2.6 PAVEMENT FAMILIES

In order to make sound management decisions, it is necessary to project the future condition of a pavement rather than just the present condition represented by the PCI. Comparing the seven airport pavement surveys spanning the last eighteen years, it is apparent that a pavement's PCI degrades over time. By grouping pavements with similar properties, it is possible to distill an "average" behavior for the group. The MicroPAVER system calls groupings of like pavements "families." The intent is that grouped pavements will tend to perform similarly as they age. If this grouping is performed successfully, documented behavior of older pavements can be used to project probable behavior for younger pavements as they age. In other words, pavements within the same family should have PCIs that are roughly the same when their ages are the same. The choice of what properties, and ultimately which pavements are used to build a family are determined by the engineer. The number of families needs to be sufficiently large to cover different pavement types while preserving a statistically significant data set from the available survey data.

The database of Montana airports was configured in 1991 for sorting of families by parameters: surface type, primary use, pavement strength, rank, and asphalt thickness to total thickness ratio. In 1997 the medium strength asphalt runways were split into two families by approximate usage, or "operations count".

Surface types include: asphalt (AC), structural asphalt overlays of asphalt (AAC) or concrete (APC), bituminous surface treatments (ST), and Portland cement concrete (PCC). Concrete pads at the surface were designated "PCC," while those overlaid with asphalt were labeled "APC." When a pavement contained 1" or more of screed-applied asphalt cement coated aggregate it was called "AC," unless it was upgraded to an asphalt overlay of asphalt (AAC) by being overlaid with 1" or more of AC or with greater than 1" of porous friction course (PFC). Single-, double-, and triple-shot surfaces were designated as surface treatments (ST). These bituminous surface treatments (BST) were upgraded to structural strength similar to asphalt and called "AC" when overlaid with 1" or more of P-401, or with greater than 1" of porous friction course (PFC).

Primary uses for airport pavements are aprons, runways, and taxiways. Sections were assigned as "Apron", "Runway", or "Taxiway" based upon their designation on FAA form 5230-1.

Pavement strengths are split into single axle loads of less than 12,500 pounds, 12,500 pounds up to and including 30,000 pounds, and over 30,000 pounds (light, medium, and heavy). Asphalt to total pavement section thickness ratio is set at less than 30%, between 30% and 70% inclusive, and over 70%. Design strength and asphalt thickness/total thickness ratio were encoded into a single character and stored into the database "Section Category" and updated for new construction. While asphalt thickness to total thickness ratio was not used in the final analysis of this report, it facilitated exploration of potential family groupings and could be used in future projects, so was not removed from the database. Pavement sections were assigned to one of ten section categories based on information shown on existing FAA Form 5320-1 for each airport. Unspecified P-609's (BST) were assumed to be double shots and assigned a nominal thickness of 1". Bituminous surface treatments (BST) and porous friction coats (PFC) were given credit for only half their nominal thickness in equivalent asphalt depth. Table 2.3 presents the section categories used and the requirements for each.

TABLE 2.3
SECTION CATEGORY CRITERIA

Section Category	AC/Total Depth Ratio	Design Strength (Single Wheel Load)
A	< 30%	< 12.5K
B	30% - 70%	< 12.5K
C	> 70%	< 12.5K
D	< 30%	12.5K - 30K
E	30% - 70%	12.5K - 30K
F	> 70%	12.5K - 30K
G	< 30%	> 30K
H	30% - 70%	> 30K
I	> 70%	> 30K
P	PCC, non-asphalt surface	

"Rank" allows prioritization of sections into primary (P), secondary (S), tertiary (T), other (X), not applicable (N), and a number of other roadway specific categories. Only two rank distinctions were used in this project-

"X" for current pavements and "N" for abandoned or non-federally funded pavement. Old pavement sections that have been removed, replaced, or reconstructed are retained in the database for calculation of family behaviors, but are excluded from all projection calculations by being ranked "N." All remaining pavements are ranked "X", to be included in current calculations and reports. Primary (P), secondary (S), and tertiary (T) could be used to prioritize heavy use airfields over lighter use fields, or to alter the built-in priority of repairing runways, then taxiways, then aprons. Ranking could be used to include external budget priorities.

In 2000, medium strength runway/taxiways were subdivided by operations estimates into those having 5000 or fewer annual operations (L), and heavy use strips averaging over 5000 (U). This separation into "light use" versus "busy" was explored with other groupings, but each lacked sufficient samplings (mostly of older pavements) to produce reliable forecasting. Operations estimates were updated using 2006 FAA 5010-1 forms and rounded to the nearest thousand up to fifteen thousand, then to the nearest 5000 for annual estimates exceeding 15,000.

In 2006, the two families of surface treatment pavements were combined, as were the two primary usages associated with low strength pavement. There were no longer enough pavements in these dwindling families to produce statistically significant groups, nor to require separate estimations.

While a number of other parameters are currently available in the database, few if any would be reasonable sort criteria. There are user definable fields for refining or redefining families as the available data set grows and it becomes possible to use additional delimiters such as "Maintained" vs. "Unmaintained," or "Harsh", "Moderate", "Minimal" to describe freeze-thaw cycle exposure at the site.

2.7 FAMILY ANALYSES

Families were assigned according to surface type, primary use, design strength (using section category values), and operations counts. These selection criteria made the most sense and produced results that fit well with common engineering judgement and measured data. Numerous grouping variations were explored with inferior results. Retaining the majority of the families used in earlier years allows meaningful comparisons with previous surveys. Family curves for all PCI system plans since 1991 are included in the appendix. The following eight families were defined, and are coded to indicate the combination of selection criteria used for each.

While there is scatter in the data that PCI families are based on, it is well within the limits expected from nearly sixty airports spread across a wide geographic region, with varying traffic loads and maintenance practices. While maintenance is great for airport pavements, the inspections that follow produce an upward spike in the pavements' "life cycle curve." These increases in PCI's over historical values create a certain amount of unavoidable "scatter" in the data. Likewise, a fog coat or crack sealant will likely age much more quickly than the original pavement; this steeper rate of decline also generates data scatter. There are a few pavement sections that exhibit an increase in successive PCI's, as well as a few with precipitous drops due to failed sealant. To compensate for the scatter we must realistically expect from the variations in the airport system, the database of accumulated PCI inspection results is statistically "screened." Six of the eight families used in this analysis generally are created from 90% of the available data, the remaining "outliers" are plotted but not used to generate the family curve; the two most populous data sets ACRML and ACRMU drop the screening and allow for a maintenance "bump" in the data.

Pavement sections that are at the extremes of the pavement performance spectrum were removed from the data set used to construct the representative family curves. The engineer established a "boundary" of theoretical best and worst possible pavement life cycles to filter out abnormal pavement wear and

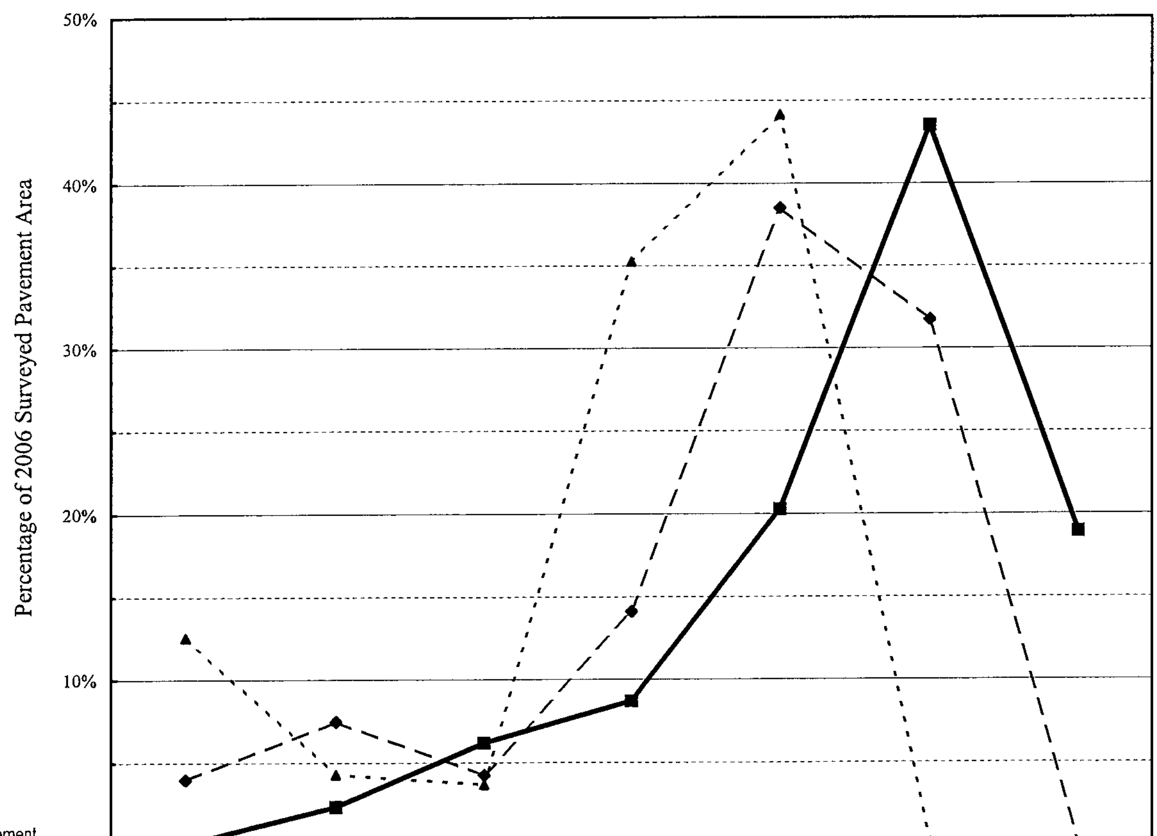
3.3 SYSTEM-WIDE PAVEMENT CONDITIONS

MicroPAVER uses current PCI values as a starting point on the pavement section's family curve, then continues down the family curve to project PCI's in the future. The constrained "best-fit" life cycle curves generated for each family are valid only to the age for which there is survey data, after which they assume a straight-line projection of the curve's slope (shown with dashed lines on the family curves). An Excel spreadsheet was used to summarize, organize, and enhance the presentation of MicroPAVER-processed information into system-wide pavement condition ratings (Figure 3.2). The Pavement Condition Ratings shown are area-weighted to portray the percentage of 2006-surveyed Montana airport pavement area falling into each rating class. Square footages for each pavement section were accumulated into one of seven Pavement Condition Ratings, based on their inspected or predicted PCI values, and the scale shown in Figure 2.2, Step 8. The pavement area in each condition rating was then converted to percentages by dividing by the total 2006-surveyed area. The resulting distribution of Pavement Condition Ratings shown in Figure 3.2 projects a representative aging of all inspected airport pavements given continued maintenance practices, but no major rehabilitation or reconstruction.

FIGURE 3.2

SYSTEM-WIDE PAVEMENT CONDITION RATINGS

"No Action" Alternative For Pavements Surveyed in 2006



Pavement Condition Ratings:	Failed	Very Poor	Poor	Fair	Good	Very Good	Excellent
2006	0.1%	2.3%	6.2%	8.7%	20.3%	43.5%	18.9%
2011	4.0%	7.5%	4.2%	14.1%	38.5%	31.7%	0.0%
2016	12.5%	4.3%	3.7%	35.3%	44.2%	0.1%	0.0%

The data in Table 3.1 and Figure 3.2 both show unequivocally that if reconstruction programs on Montana airports were suspended or discontinued, airport pavements would degrade to marginal serviceability within about 10 years. While there are many finer points to be gleaned from the graph of system-wide pavement condition ratings (Figure 3.2), splitting the pavement ratings into three groups (below fair, fair, and above fair) will help translate the extensive data set to more comprehensible insights.

Pavements rated as "Fair" are generally in a state of transition on two fronts: surface defects are beginning to be noticeable in both type and frequency, and the expense of reconstruction is becoming more economical than continued preventative maintenance. While surface distresses indicating deterioration of the pavement/base course system are visible, they are subtle enough to not have major effects on ride quality nor are they generating significant foreign object debris (FOD). Studies continue to indicate that reconstruction of "good" to "fair" quality asphalt surfacing is more economical than waiting until major distresses appear. While it may seem counterintuitive to reconstruct good-looking pavement, reconstruction before the gravel base deteriorates is much less expensive. The area of transitional pavements in the absence of reconstruction is projected to escalate from 9% to 14% to 35% in the years 2006, 2011, and 2016, respectively.

Those pavements rated above "Fair" are high-quality surfaces providing trouble-free use and relatively low maintenance costs. Currently, lower cost preventative maintenance is the recommended course of action for 83% of the pavement area at the 50 airports surveyed. Without investments in (re)construction, the area of pavement in this high service/low cost maintenance class drops to 70% in five years and 44% in 10 years.

Pavements assessed as below "Fair" condition provide increasing maintenance headaches, growing probabilities of damaging aircraft, decreasing ride quality, and escalating repair and reconstruction costs. "Below fair" pavements range from showing noticeable defects, all the way to near gravel surfaces. These serviceable, but low quality pavements grow from 9% (by area) of the 2006 pavement area to 16% and 21% of the state-wide system pavements in 2011 and 2016, respectively.

This prediction is based on the assumption that current maintenance practices, aircraft activity, and loadings will continue, and that no new construction or major reconstruction will occur. In other words, they show what would happen if Montana airports discontinued pavement construction / reconstruction programs.

3.4 MAINTENANCE PRIORITIES

As an aid to pavement maintenance project prioritization three summary tables have been constructed using PCI projections from Table 3.1. These tables consider project prioritization from a system-wide approach, a community-based vantage, and a "maintain vs. reconstruct" option. These summary tables are meant only as an "early warning indicator" and should not be misconstrued as being an absolute authority. Where a rehabilitation or reconstruction project has been completed since the most recent PCI inspection, projections are shown with a ~~strike out~~.

Preserving the current investment in Montana's general aviation (GA) airport pavements may include prioritizing maintenance projects as in Table 3.2. Fog seals, crack sealing, and thin-lift overlays *applied as the pavement nears or crosses its critical PCI* are the most economical way of extending pavement life. By prioritizing projects by their square footage, it's possible to allocate state and federal dollars to best extend the life of the greatest pavement area. Table 3.2 can be used to guide a *system-wide approach to economical pavement maintenance.*

elaborate webs of costs and consequences of specific remedies to be applied to specific grades of distress.

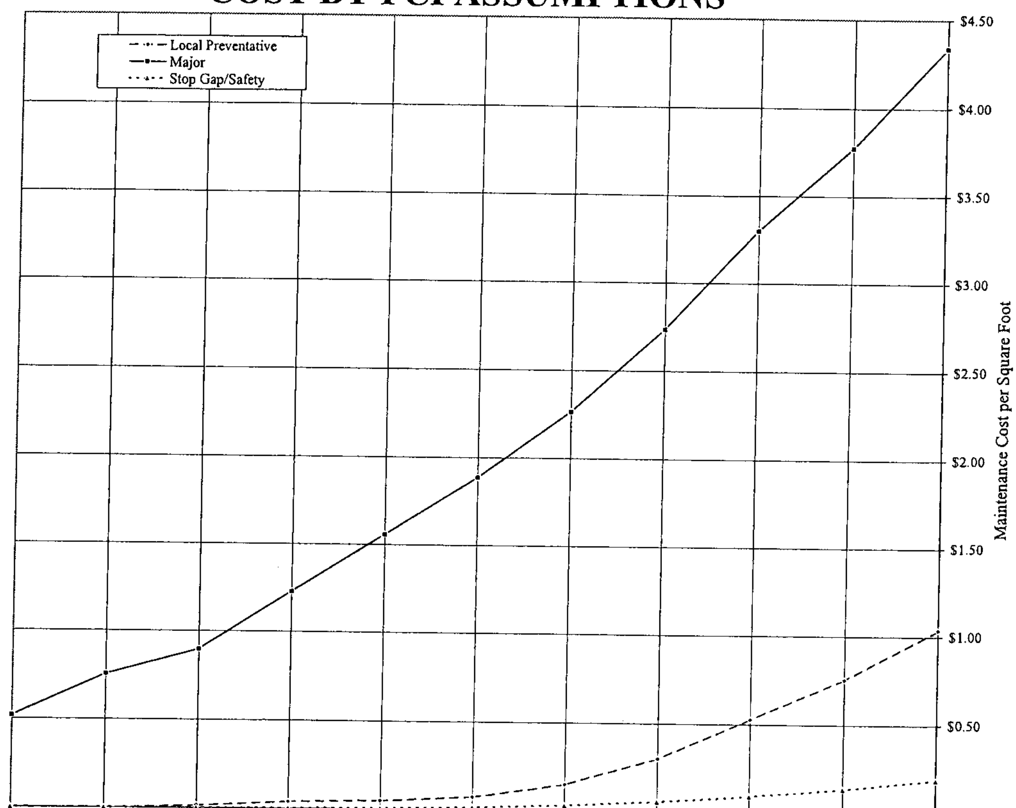
The first step in establishing a work plan is to determine the scope of application. This scope may be restricted for such reasons as reducing computing time, or exploring optimum repair strategy at a single airport. Within the Selection Criteria option of the work plan, the user may select "All Items" to get past and present pavement sections stored in the database, or choose "Build Selection" to construct a smaller group. To choose currently maintained pavements filter using "Rank = X," i. e. select all pavements that have been classified as "current" (This is the same as previous MicroPAVER versions' "Network Report"). Airports can be addressed individually by setting "Zone" equal to the airport's four-character code **and** setting "Rank = X." Smaller selections are filtered out using "BranchID" or "SectionID."

The **Minimum Condition Report** is the simplest of the modeling routines. This report allows the user to set a single PCI minimum for each future year, then calculates the cost to repair any pavement that falls below these predetermined minimums. Costs of improvements increase with decreasing PCI and are calculated from a 1994 composite of nation-wide Department of Defense airfield maintenance costs (see Figure 3.3). These PCI-based repair cost estimates are a systematic reflection of increasing repair costs for decreasing pavement quality. The minimum allowable PCI can be set for each year in the future to phase in repairs acceptable to available funding. For example, budget constraints might only allow raising the system-wide minimum PCI to 35 the first year, but this could then be raised to 41, 46, and 50 in successive years. Major M&R budgeting is predicted reasonably well for any number of years with little change in the validity of the results.

The **Consequence Model Report** treats extrapolated distress quantities with specific remedies (see Table 3.5) to remediate pavement distresses and increase the overall section PCI. For a preset cost (see Table 3.6) the pavement distress associated with the treatment replaces the original more severe distress in PCI calculations (see Table 3.7). For example, crack sealing AC pavements costs about one dollar and forty cents per linear foot and fills medium- and high-severity cracks, reducing them to low-severity cracks. If an airport owner paid for recommended repairs to each pavement distress on their pavement and had their airport inspected immediately after completion of the repairs, the airport's new PCI and the bill for improvements would be approximately that predicted by the Consequence Model Report. The Consequence Model Report uses only localized repair options and makes no attempt to increase quantity or severity of distresses to account for the natural aging process nor to project distresses that have not already been recorded during an inspection. This report is designed to provide projections of the localized repair costs and consequences *only when repairs are applied within a year of the airport inspection.*

The **Limit to Budget Report** optimizes pavement quality using a set budget cap and four targeted maintenance policies: Localized Safety, Localized Preventative, Global, and Major Reconstruction. Localized Safety treatments attempt to keep an airport pavement safe for operation using only local treatments while waiting for funds to replace the entire pavement section. For example, a high severity depression could be patched to eliminate hydroplaning potential, but underlying subgrade problems could still necessitate eventual reconstruction. Local Preventative treatments are applied to above-critical-PCI pavements to prolong the pavement life and reduce the effect of nonstructural and minor structural local defects. Crack sealing is a common Local Preventative repair that will stop moisture penetration into the subgrade and preserve subgrade integrity and extend pavement life. Global Preventative measures are applied to above-critical-PCI pavements when defects affect the whole surface. Raveling can be slowed significantly by applying a surface seal, rebinding the aggregate into a high quality surface at a fraction of the cost of a new surface. Major M&R is a total reconstruction of a pavement section applied when that section is below the critical PCI for its family curve, or if alligator cracking, rutting, and the like, indicate structural failure even above the critical PCI. The "Major Under-Critical" case of Major M&R assumes that the critical PCI was chosen such that reconstruction is a more economical option than continued maintenance once a section has passed below its critical PCI. While it is very rare, structural failure of parts of a section may produce an unusable pavement with a PCI rating above critical. This "Major Above-Critical" special case can only be treated effectively by reestablishing a sound foundation for the surface layer, hence its inclusion in the Major M&R policy.

FIGURE 3.4
COST BY PCI ASSUMPTIONS



CATEGORY \ PCI	100	90	80	70	60	50	40	30	20	10	0
Local Preventative	$0.0000	$0.0000	$0.0151	$0.0377	$0.0498	$0.0754	$0.1509	$0.3017	$0.5281	$0.7544	$1.0380
Major	$0.5190	$0.7544	$0.8962	$1.2266	$1.5555	$1.8859	$2.2631	$2.7353	$3.2996	$3.7718	$4.3376
Stop Gap/Safety	$0.0000	$0.0000	$0.0015	$0.0030	$0.0075	$0.0166	$0.0332	$0.0573	$0.0920	$0.1358	$0.1916

The Limited to Budget Report is an hybrid report which makes the best use of detailed inspection data for short-range predictions then switches to a more general, empirically verified long-range scheme. The first year predictions are based on a Consequence Model Report plus Global and Major repair options, while successive years use the same costs (see Figure 3.6) as the Minimum Condition Report. First year predictions of costs for local maintenance and conditions are determined from Localized Safety and Localized Preventative Maintenance Policies (Table 3.5) and their associated cost and consequence tables (Tables 3.6 and 3.7). In succeeding years, both Localized Safety and Preventative Maintenance costs are determined from the Cost by PCI table illustrated in Figure 3.4. Global M&R always takes its costs and consequences from user defined values irrespective of pavement PCI's (see Table 3.8). In other words fog seals will have the same cost and useful life regardless of the quality of pavement they're applied to. Major Rehabilitation costs for all projection years are used from the Cost by PCI table in Figure 3.4.

TABLE 3.5
FIRST YEAR LOCALIZED MAINTENANCE POLICIES

LOCALIZED SAFETY OR "STOP-GAP"

Description	Severity	Treatment
Alligator Cracking	H	Patching - AC Deep
Block Cracking	H	Crack Sealing - AC
Depression	H	Patching - AC Deep
Jt. Ref. Cracking	H	Crack Sealing - AC
L & T Cracking	H	Crack Sealing - AC
Patching	H	Patching - AC Deep
Weath/Ravel	H	Patching - AC Shallow
Rutting	H	Patching - AC Deep
Shoving	H	Patching - AC Shallow
Slippage Cracking		Patching - AC Shallow
Swelling	H	Patching - AC Deep
Blow-Up	M	Patching - PCC Full Depth
Blow-Up	H	Patching - PCC Full Depth
Corner Break	H	Patching - PCC Full Depth
Linear Cracking	H	Crack Sealing - PCC
Durability Cracking	H	Slab Replacement - PCC
Small Patch	H	Patching - PCC Partial Depth
Large Patch/Utility	H	Patching - PCC Full Depth
Scaling/Crazing	H	Slab Replacement - PCC
Shattered Slab	H	Slab Replacement - PCC
Joint Spalling	H	Patching - PCC Partial Depth
Corner Spalling	H	Patching - PCC Partial Depth

LOCALIZED PREVENTATIVE

Description	Severity	Treatment
Alligator Cracking	H	Patching - AC Deep
Alligator Cracking	M	Patching - AC Deep
Block Cracking	H	Crack Sealing - AC
Block Cracking	M	Crack Sealing - AC
Depression	M	Patching - AC Deep
Depression	H	Patching - AC Deep
Jt. Ref. Cracking	H	Crack Sealing - AC
Jt. Ref. Cracking	M	Crack Sealing - AC
L & T Cracking	M	Crack Sealing - AC
L & T Cracking	H	Crack Sealing - AC
Oil Spillage		Patching - AC Shallow
Patching	M	Patching - AC Deep
Patching	H	Patching - AC Deep
Rutting	H	Patching - AC Deep
Rutting	M	Patching - AC Deep
Shoving	H	Patching - AC Shallow
Shoving	M	Patching - AC Shallow
Slippage Cracking		Patching - AC Shallow
Swelling	H	Patching - AC Deep
Swelling	M	Patching - AC Deep
Blow-Up	L	Patching - PCC Full Depth
Blow-Up	M	Slab Replacement - PCC
Blow-Up	H	Slab Replacement - PCC
Corner Break	H	Slab Replacement - PCC
Corner Break	M	Patching - PCC Full Depth
Linear Cracking	H	Crack Sealing - PCC
Linear Cracking	M	Crack Sealing - PCC
Durability Cracking	H	Slab Replacement - PCC
Durability Cracking	M	Patching - PCC Full Depth
Small Patch	M	Patching - PCC Full Depth
Small Patch	H	Patching - PCC Full Depth
Large Patch/Utility	H	Slab Replacement - PCC
Large Patch/Utility	M	Patching - PCC Full Depth
Scaling/Crazing	H	Slab Replacement - PCC
Scaling/Crazing	M	Slab Replacement - PCC
Faulting	H	Slab Replacement - PCC
Shattered Slab	M	Slab Replacement - PCC
Shattered Slab	H	Slab Replacement - PCC
Joint Spalling	H	Patching - PCC Partial Depth
Joint Spalling	M	Patching - PCC Partial Depth
Corner Spalling	M	Patching - PCC Partial Depth
Corner Spalling	H	Patching - PCC Partial Depth

TABLE 3.6
FIRST YEAR LOCALIZED MAINTENANCE COSTS

Repair Description	Cost
Crack Sealing - AC	$1.40/ft
Patching - AC Deep	$34.00/sf
Patching - AC Shallow	$14.00/sf
Crack Sealing - PCC	$1.40/ft
Patching - PCC Full Depth	$61.00/sf
Patching - PCC Partial Depth	$75.00/sf
Slab Replacement - PCC	$61.00/sf

TABLE 3.7
EXAMPLE FIRST YEAR REPAIR CONSEQUENCES

Crack Sealing - AC

Distress Description	Severity	New Distress Description	New Severity
Block Cracking	M	Block Cracking	L
Block Cracking	H	Block Cracking	L
Jt. Ref. Cracking	M	Jt. Ref. Cracking	L
Jt. Ref. Cracking	H	Jt. Ref. Cracking	L
L & T Cracking	M	L & T Cracking	L
L & T Cracking	H	L & T Cracking	L

TABLE 3.8
GLOBAL MAINTENANCE COSTS AND CONSEQUENCES

Repair Description	Cost	Application Interval	Years for PCI to Return to Preapplication Value
Overlay - AC Thin (Global)	$0.70/sf	10	5
Surface Seal - Fog Seal	$0.08/sf	5	2

Money is first allocated to sub-critical PCI sections for "stop gap" Localized Safety treatments. If it's determined later that funding is available for major reconstruction of a section, then its stop-gap funds are redistributed. The second fiscal priority is to prolong the life of above-critical-PCI pavements with Local, then Global Preventative treatments. Local and Global Preventative funds are the example $1 invested near the critical PCI as shown in Figure 2.12 to avoid the necessity of spending $4 to $5 later. This investment in pavements before rapid deterioration produces an extended pavement life cycle as shown in Figure 3.2 and optimizes pavement quality per dollar spent. Major Under Critical and Major Above Critical repair treatments are prioritized for replacement by PCI and primary use as shown in Table 3.9.

TABLE 3.9
EFFECTIVE MAJOR M&R PRIORITIES

M&R Policy	PCI Range	Runways	Taxiways	Aprons
Major Above-Critical	100 - 70	2	4	6
	70 - Critical	1	3	5
Major Under-Critical	Critical - 40	1	3	5
	40 - 0	2	4	6

3.7 OTHER MICRO PAVER REPORTS (Available, but not included in this System Plan Update)

MicroPAVER provides several reporting options that are not included in this report since they do not directly address the intent of this project. They are briefly discussed here to provide insight on the potential advantages of implementing the pavement management system.

The **Inspection Schedule Report** allows the user to plan which pavements need to be inspected based on their current and expected conditions. This allows the user to time inspections for maximum effectiveness in identifying pavements in critical need of maintenance and/or reconstruction.

The **Condition History Report** allows the user to plot a specific pavement's history of PCI values through all of its existing PCI inspections. This option gives the user an at-a-glance assessment of an individual airport pavement's performance over time. This is available in graphical and tabular form under the heading "Condition Table" as part of the M&R Report, but was not included in this text.

The MS Excel spreadsheets included in this report as Tables 2.4 and 3.1 can also be manipulated to perform many of the tasks possible in the MicroPAVER database. Depending on the computer equipment available and the expertise of the user, this spreadsheet format may be more convenient for some types of analysis.

MicroPAVER provides several other analysis routines to help the user decide among various maintenance and repair alternatives. These analysis and reporting options provide decision making information that may be useful for evaluating system-wide programs or for individual airport planning.

3.8 CONTINUED MICROPAVER IMPLEMENTATION

In addition to this report, the product for this 2006 Update to the Montana Aviation System Plan includes an up-to-date copy of the pavement database, and a current licensed copy of the MicroPAVER software. This will allow the Montana Aeronautics staff to use the software and database in their planning and budgeting efforts. Inspection reports and airport maps will be provided to Montana Aeronautics in a compatible format for inclusion on their web site where they will be available to the public. Excerpts of the information contained in the reports are provided directly to airport sponsors, so they have a current indication of their pavement conditions and needs.

The continued success of this pavement management system is dependent on ongoing efforts to keep the database up to date. PCI surveys, conducted on a regular three-year cycle beginning in 1988, have collected pavement condition information for 59 of Montana's airports. Continued implementation of the current family models need not include surveys of each airport each time an update is completed. Instead, the frequency of inspections at each airport should be based on the likelihood of significant change since the last inspection. If previous survey results indicate an approaching PCI plateau, an airport could be skipped for a phase or two, allowing additional airports to be surveyed on available funds. Conversely, survey frequency should increase as conditions approach the critical PCI. The frequency of inspections at any given airport may also be based on the importance of that airport to the system, or the sponsor's needs for information to assess their maintenance and construction programs. *Updates to the pavement condition database should contain surveys of several airports at near failure, pre-project condition to ensure that prediction curves are accurate throughout the entire pavement life. Current curves lack significant data to set/validate long-range pavement behavior.*

The PCI survey program depends on consistent inspection information to provide accurate and reliable estimates of condition and predictions of future condition. This is best achieved through strict compliance with the requirements of FAA Advisory Circular 150/5380-6 with the modifications from the Northwest Mountain Region handout "Pavement Condition Survey Program", since MicroPAVER is designed to work with these procedures. Personnel selected to conduct the PCI visual inspections should be well-trained, and experienced in the procedures outlined in these documents, to ensure the needed quality and consistency of data.

The program also benefits from close attention to detail in documenting the inspection and analysis processes. The MicroPAVER database, if properly maintained, preserves much of this data. FAA Forms 5320-1 also provide much of the needed information about pavement design criteria, and the definitions of sections and sample units. It is very important that these forms and the information they contain for Montana airports continue to be updated as changes occur, and that the information is updated in the MicroPAVER database. Coordination with the FAA, airport sponsors, and engineers working on airport improvement projects is essential in maintaining up-to-date records of the pavement systems in the database. Additional information, such as the spreadsheet summaries provided in this report should be carefully updated or noted as obsolete when database updates occur. Additionally, the MicroPAVER database may be compatible with other airport information management systems, providing a powerful combination of information in convenient formats. Because of the architecture of the database, it can be coordinated with other programs. Such efforts may require direct coordination with the developers of the program at the United States Army Corps of Engineers Research Labs.

Predictions developed for this update use a slowly evolving set of families. As noted earlier in Chapter 3 of this report, family analysis curves can be re-defined in any way the user desires. Results obtained in this update suggest that maintenance practices actually occurring on Montana's airports may play an increasingly important role in slowing pavement aging. As a result, future updates to the plan may be improved by increased attention to actual maintenance on each pavement section, and revised family analysis curves that account for differences in maintenance. Changes to the family analysis curves should not be undertaken without careful analysis however, since consistency of results is of great importance to the success of the program. Two rounds of inspections under a new maintenance regimen and increased federal investment in Montana's airport infrastructure does not yet provide enough data to split families into "well-maintained" and "poorly-maintained" groups. Most of the current families do not have enough survey points to divide without compromising the statistical validity of the data, especially on the aged end of the graph. In fact, should excellent maintenance continue, the database will not add any "below critical PCI" information; and while this will be good news to airport users, it adds more uncertainty to end-of-cycle PCI predictions.

Even with Montana's current wealth of data (using all inspections from 1988-2006; roughly 2370 PCI determinations from 31,000 recorded distresses) we are probably limited to 5-15 families. It is a very fine line between having enough types of families to fairly accurately model the different pavements in the state, and having too many families to be accurately defined by the existing data. To be "well-defined" a family must have inspections of representative pavements at a good range of ages. If pavements are less representative of the group, or data is lacking for a cluster of ages (especially the downward curve after critical PCI) a family can only be constructed with a good deal of engineering judgement, and as such, it may represent that judgement, more than the empirical reality. The challenge becomes choosing which few of the numerous common-sense delimiters create families with good statistical properties.

As this pavement management system evolves, it may be appropriate to slowly phase in one or more new criteria (maintenance practices, freeze-thaw cycling, insolation, etc.) in place of, or in addition to the current five criteria (pavement type, functional use, design load, operations counts) while trying to maintain approximately 10 families. For example, operations counts were phased into the most data-rich family in 2003 as a way to split an overly large set (ACRM became ACRML and ACRMU). Functional usage was dropped from the light-duty design load pavements in 2006 creating two families where formerly there were four. There were not nearly enough "under 12,500 lb design load" or "surface treatments" remaining in the State to warrant four families, so ACAL and ACRL were combined into ACPL, while STAA and STRA were lumped into STPA.

Appendix Figure A.1 is included to illustrate that the current set of families is fairly robust, although it also hints at how the high-age end of the graphs (with the least data) can show significant variation from year to year. Note how slight raising of the 0-5 year portions of each graph reflect a number of reconstructed airports and improving early preventative maintenance.

Finally, the Montana airport pavement database and associated software systems can only provide benefits if they are actively used to help manage Montana's airport pavements. The entire purpose of the program is to provide information to decision makers. Whether it is used by the Montana Aeronautics Division, the Federal Aviation Administration, airport sponsors, planners, or engineers, the system can be used to provide meaningful information about pavement conditions, performance, policies, and budget allocations.